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A Method for Estimating Depot Overhaul Requirements of Combat Vehicles

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Depot Overhaul Requirements
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RESEARCH ANALYSIS CORPORATION

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A METHOD FOR ESTIMATING DEPOT OVERHAUL REQUIREMENTS FOR COMBAT VEHICLES

PROBLEM

To provide a management tool for establishing depot overhaul requirements for combat vehicles in balance with vehicle use, overhaul capacity, and float quantities.

FACTS

A sample of new-generation combat vehicles, in USAREUR since delivery from manufacturer, is under current RAC study for examination of replacement and maintenance policies. This sample consists of 615 M60 tanks, 554 M113 armored personnel carriers, and 77 M88 tank-recovery vehicles.

On the basis of a previous RAC study* the Army had planned to overhaul combat vehicles after 3000 miles and before 4000 miles of use. As mileage on the new vehicles has accumulated about twice as fast as on the older models, many are nearing or have passed 3000 miles of use. The current study or other circumstances may suggest a change in the plan.

DISCUSSION

Scheduling depot overhaul at a specific mileage introduces problems of programming, budgeting, and facility planning. Weighing a number of alternative actions is required to achieve satisfactory solutions.

In the process of investigation the five basic elements of the problem were summarized as follows: (a) accumulated use at time of overhaul, (b) rate of vehicle use, (c) overhaul float, (d) duration of overhaul, and (e) overhaul capacity. Duration of overhaul is the total elapsed time from the vehicle's removal from use in the fleet to its return. Overhaul float is the number of vehicles required to be added to the in-use fleet to replace those removed for the duration of overhaul.

Using the concept of the five basic elements a formula was developed (in App A) that measures the interrelation of these elements. In the system represented, accumulated use is uniformly distributed over the use interval before

*Research Analysis Corporation, "Operation, Maintenance, and Cost Experience of the Tank, Armored Personnel Carrier, and Self-Propelled Howitzer Vehicle Fleets (U)," RAC-T-409, Sep 62. SECRET
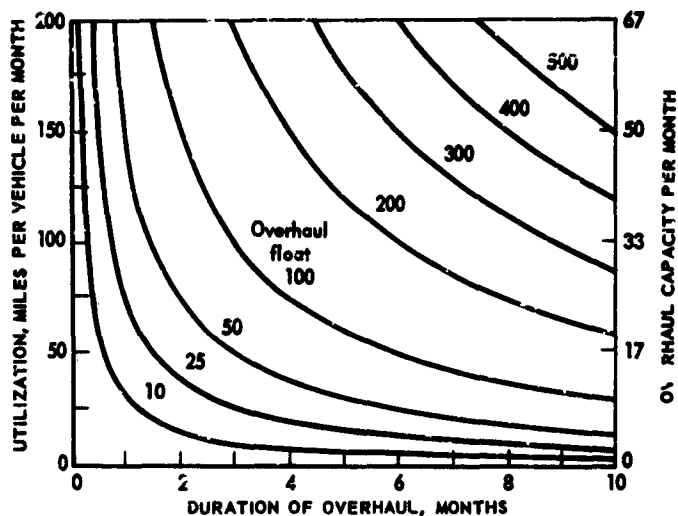
Fig. 1—Relation of 3000-Mile Overhaul Interval to Other Overhaul
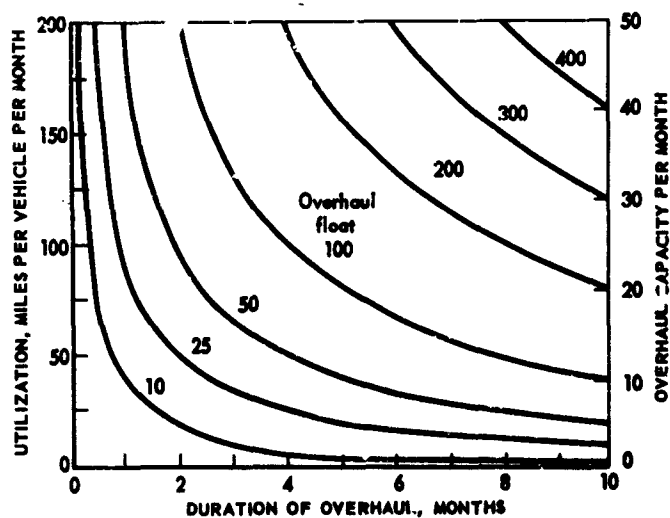Requirements per 1000 In-Use Vehicles

Fig. 2—Relation of 4000-Mile Overhaul Interval to Other Overhaul
Requirements per 1000 In-Use Vehicles

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overhaul. If the distribution were not uniform, overhaul requirements could exhibit peaks and valleys, but mileage distribution of the M60 tank sample under study shows approximate uniformity. Thus there seems little advantage in generating quantities of tables and figures describing possible changing effects.

Simply put, the formula is based on a line of reasoning of which the following is an example:

A tank with a rate of use of 200 miles per month that is to be permitted accumulated use of 3000 miles before overhaul will be overhauled after 15 months. For 1000 tanks in use, required average overhaul capacity would then be 66⅔ tanks per month. If the duration of overhaul is 9 months the overhaul float requirement would be 66⅔ × 9 or 600 tanks.

Utilizing the formula, the appendix records calculated values for selected points for each of the five elements (see App A, Table A1). These values are shown graphically in Figs. 1 and 2. Figure 1 shows the relations of the remaining four elements when the accumulated-use factor is established at 3000 miles; Fig. 2 shows similar computations for 4000 miles. Use of these graphs is illustrated as follows:

If it is planned to overhaul a vehicle fleet after 3000 miles of accumulated use, Fig. 1 is selected. The first limiting factor may be considered to be that the fleet is utilized about 90 miles per month. To maintain this rate of utilization the required overhaul capacity per month per 1000 vehicles in use can be read from the right vertical scale at the point opposite 90. In this case the balancing overhaul capacity is 30. If required, utilization rate and overhaul capacity may be brought into balance by adjusting either. If neither adjustment is feasible, the balance may be restored by extending the accumulated use before overhaul. Thus, in Fig. 2, where the same relations are shown on the basis of overhaul at 4000 miles, the balancing overhaul capacity is reduced to 22 rather than 30.

If this is acceptable the next step is to determine the duration of overhaul, which is essential to measurement of the overhaul float requirements. Table 1 shows how the duration of overhaul can be estimated.

TABLE 1

ESTIMATED DURATION OF OVERHAUL

Action	Time, months
Vehicle withdrawn from unit and assembled at a collection point for shipment	1.0
Shipped from collection point to overhaul depot	0.5
Inspected, costs estimated, parts ordered, and entry to overhaul awaited	3.0
Time spent overhauling vehicle	0.5
Shipping-out orders awaited	3.0
Shipped to distribution point	0.5
Issued to unit	0.5
Total	9.0

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If this hypothetical 9-month estimate is used as the duration of overhaul on the horizontal scale and a 90-mile-per-month use rate is used on the left vertical scale, with overhaul at 4000 miles (Fig. 2), the overhaul float per 1000 vehicles in use can be read at the intersection of a horizontal line from 90 on the left vertical scale and of a vertical line from 9 on the horizontal scale. In this example the overhaul float would be 200.

The basic merit of the figures is the ease with which the effect of limiting factors can be studied in relation to other factors of the problem. While new vehicles from production are available such production quantities can be used in Figs. 1 and 2 as the equivalent of (i.e., instead of) overhaul capacities, provided it is understood that such action leaves an equivalent number of vehicles that have not been overhauled at the mileage point selected.

The figures also illustrate the degree to which imbalance in overhaul capacity can be buried in what the figures designate as "overhaul float," but which could be called "pipeline for overhaul." However, although the numbers are the same, the vehicles are different in the overhaul float and in the pipeline for overhaul. In the example based on Fig. 2, a 9-month pipeline containing 200 vehicles needs an overhaul capacity of only 22 vehicles per month to maintain balance; if this capacity is halved and the vehicles that would have been overhauled accumulate in the pipeline, in 9 months this increase would be 99 (9 months' slippage times 11). This would only increase the pipeline and overhaul float quantities 50 percent.

The penalty paid for unbalanced overhaul capacity is this: If capacity is too low, either vehicles are held in use beyond the overhaul point until balance occurs, or unserviceables are accumulated indefinitely at a rate which is the difference between the actual and balancing capacity. If capacity is too high during some period, part of the capacity will be unused.

Both figures illustrate two important points: First, for implementation of a policy based on overhaul after a set use interval, overhaul capacity should be balanced with use. Temporarily such balance can be secured by receipts of new vehicles from production if such are available. Second, over short periods of time neither overhaul capacity nor time consumed by the overhaul itself is an important contributor to a requirement for overhaul float. Requirements for overhaul float are caused by duration of overhaul. The detailed means of reducing the duration of overhaul are beyond the scope of this paper; they are many and varied. To name only a few:

Overhauling nearer user to reduce in-transit time.
Prepositioning and advance delivery of parts.
Tighter scheduling of vehicle turnaround from user to depot to user.

By use of the formula in App A the values for any set of assumptions can be computed. However, values estimated by inspection of Figs. 1 and 2 are considered sufficiently accurate for planning purposes.

CONCLUSION

Figures 1 and 2 may serve as a tool for preliminary planning of depot overhaul capacity in relation to vehicle utilization. They demonstrate the inevitable relation among accumulated use at overhaul, rate of use, overhaul float, duration of overhaul, and overhaul capacity.

Appendix A

COMPUTATIONS

ASSUMPTIONS

Vehicles have two states: in use with the fleet or out of use in overhaul; fleet mileage is distributed uniformly. Mean overhaul float requirements D depend on vehicle utilization u, miles per month; mileage at overhaul M; duration of overhaul λ, months; and density of the in-use fleet supported N, 1000 vehicles.

METHOD

First estimates of overhaul float requirements may be derived by modification of an existing steady-state model of availability potential B. Availability potential is defined as $B = 1/(1 + k\lambda)$, where k = rate of entry into overhaul per vehicle per month. With overhaul entry controlled by vehicle mileages, k becomes a function of the vehicle use rate. The total fleet is of a size R, and $BR = N$. Hence $R = N(1 + k\lambda)$.

Therefore the overhaul float requirements are

$$D = R(1-B) = N\left(1 + k\lambda\right)\left(1 - \frac{1}{1+k\lambda}\right) = Nk\lambda$$

Since the vehicle use rate is u miles per month, $k = u/M$. Making this substitution in the formula above

$$D = \frac{Nu\lambda}{M} \text{ or } \lambda = \frac{M}{N} \times \frac{D}{u}$$

By definition, overhaul capacity $C = D/\lambda$. This formula was applied to the development of the data in Table A1, in which M is 3000 miles in the top half, and 4000 miles in the bottom half, and the other terms are as defined above in "Assumptions."

The representative values in Table A1, top half and bottom half, have been used as plot points for the construction of Figs. 1 and 2, respectively, in the "Summary."

TABLE A1

RELATION OF OVERHAUL INTERVAL TO OTHER OVERHAUL REQUIREMENTS PER 1000 IN-USE VEHICLES

(λ = duration of overhaul, months; C = overhaul capacity, vehicles per month)

Fleet utilization μ, miles per month	Overhaul float requirements D															
	D = 10		D = 25		D = 50		D = 100		D = 200		D = 300		D = 400		D = 500	
	λ	C	λ	C	λ	C	λ	C	λ	C	λ	C	λ	C	λ	C
Overhaul at 3000 Miles																
10	3	3.3	7.5	3.3	15	3.3	—	—	—	—	—	—	—	—	—	—
25	1.2	8.3	3	8.3	6	8.3	12	—	—	—	—	—	—	—	—	—
50	0.6	16.7	1.5	16.7	3	16.7	6	—	12	—	—	—	—	—	—	—
75	0.4	25	1	25	2	25	4	—	8	—	12	—	—	—	—	—
100	0.3	33	0.7	33	1.5	33	3	—	6	—	9	—	12	—	—	—
125	0.2	42	0.6	42	1.2	42	2.4	42	4.8	42	7.2	42	9.6	42	—	—
150	0.2	50	0.5	50	1	50	2	50	4	50	6	50	8	50	10	50
175	0.2	58	0.4	58	0.9	58	1.7	58	3.4	58	5.1	58	6.9	58	8.6	58
200	0.1	—	0.4	—	0.7	67	1.5	67	3	67	4.5	67	6	67	7.5	67
Overhaul at 4000 Miles																
10	4	2.5	10	2.5	—	—	—	—	—	—	—	—	—	—	—	—
25	1.6	6.2	4	6.2	8	6.2	16	6.2	—	—	—	—	—	—	—	—
50	0.8	12.5	2	12.5	4	12.5	8	12.5	16	12.5	—	—	—	—	—	—
75	0.5	19	1.3	19	2.6	19	5.3	19	10.6	19	—	—	—	—	—	—
100	0.4	25	1	25	2	25	4	25	8	25	12	25	—	—	—	—
125	0.3	31	0.8	31	1.6	31	3.2	31	6.4	31	9.6	31	12.8	31	—	—
150	0.3	38	0.7	38	1.3	38	2.6	38	5.3	38	8	38	10.6	38	—	—
175	0.2	44	0.6	44	1.1	44	2.3	44	4.6	44	6.9	44	9.1	44	11.4	44
200	0.2	50	0.5	50	1	50	2	50	4	50	6	50	8	50	10	50